



Available online at
SciVerse ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en



ORIGINAL ARTICLE

Histologic study of periprosthetic osteolytic lesions after AES total ankle replacement. A 22 case series



F. Dalat^{a,*}, R. Barnoud^b, M.-H. Fessy^{a,c}, J.-L. Besse^{a,c},
the French Association of Foot Surgery (AFCP)¹

^a Hospices Civils de Lyon, Centre Hospitalier Lyon-Sud, Service de chirurgie Orthopédique et Traumatologique, 69495 Pierre-Bénite cedex, France

^b Service d'anatomo-pathologie, Hospices Civils de Lyon, Hôpital de la Croix-Rousse, 69004 Lyon, France

^c Université Lyon 1, IFSTTAR, LBMC UMR-T 9406 - Laboratoire de Biomécanique et Mécanique des Chocs, 69675 Bron cedex, France

Accepted: 10 April 2013

KEYWORDS

Total ankle arthroplasty;
Periprosthetic osteolysis;
Histology

Summary

Introduction: Medium-term results for total ankle replacement (TAR) are in general satisfactory, but there is a high redo rate for periprosthetic osteolysis associated with the AES implant.

Hypothesis: Comparing radioclinical findings and histologic analysis of implant revision procedure specimens can account for the elevated rate of osteolysis associated with the AES TAR implant.

Material and method: In a prospective series of 84 AES TAR implants (2003–2008), 25 underwent revision for osteolysis (including three undergoing revision twice) at a mean 59.8 months. Eight patients had hydroxyapatite (HA) coated models and the others had titanium-hydroxyapatite (Ti-HA) coatings. Radiographs were systematically analyzed on Besse's protocol and evolution was monitored on AOFAS scores. The 94 specimens taken for histologic analysis during revision were re-examined, focusing specifically on foreign bodies.

Results: Macroscopically, no metallosis or polyethylene wear was found at revision. AOFAS global and pain scores fell respectively from 89.7/100 at 1 year postoperatively to 72.9 before revision and from 32.5/40 to 20.6/40, although global scores were unchanged in 25% of patients. Radiologically, all patients showed tibial and talar osteolytic lesions, 45% showed cortical lysis and in 25% the implant had collapsed into the cysts. All specimens showed macrophagic granulomatous inflammatory reactions in contact with a foreign body; the cysts showed necrotic

* Corresponding author. Service de chirurgie orthopédique, de traumatologie et de médecine du sport (Pr MH Fessy), Centre Hospitalier Lyon-Sud, chemin du Grand-Revoynet, 69495 Pierre-Bénite, cedex, France.

E-mail address: fred.dalat@hotmail.fr (F. Dalat).

¹ Clinique du Parc, 155 ter, boulevard Stalingrad, 69006 Lyon, France.

remodeling. Some of the foreign bodies could be identified on optical histologic examination with polyethylene in 95% of the specimens and metal in 60% (100% of HA-coated models and 33.3% of Ti-HA-coated models). Unidentifiable material was associated: a brownish pigment in Ti-HA-coated models (33.3%) and flakey bodies in 44.4% of the HA-coated models and 18.2% of the Ti-HA-coated models.

Discussion: The phenomenon of periprosthetic osteolysis is still poorly understood, although implant wear debris seems to be implicated. All the patients with HA-coated implants with modular tibial stem had metal particles in the tissue around the implant, although their exact nature could not be determined. The double-layer Ti-HA coating may induce delamination by fretting while the biological bone anchorage is forming.

Level of evidence: Prospective cohort study – Level IV.

© 2013 Elsevier Masson SAS. All rights reserved.

Introduction

Total ankle replacement (TAR) is currently an acceptable treatment for degenerative ankle lesions of whatever cause [1–3]. Ten-year implant survivorship, however, was only 62% to 72% in the Scandinavian registries [4–7], compared to 80% to 90% as in series mainly reported by the designers [8,9], and 90% to 98% for hip and knee replacements [10].

Periprosthetic radiolucency and osteolysis has been little or poorly analyzed in TAR series. Massive “ballooning” periprosthetic osteolysis was reported mainly in connection with the Agility implant (a 2-component model much used in the USA), with a rate of 15% and 8.5% implant subsidence in Ketch’s series [11] of 132 implants at 9 years’ mean follow-up.

In 2009, our team reported a prospective series (2003–2006) of 50 Ankle Evolutive System (AES) TARs [12], showing 29% and 22% rates of severe (>1 cm) tibial and talar cysts respectively, at 45 months follow-up. This cystic osteolysis induced mechanical complications due to tibial and talar cortical microfracture, notably involving collapse of the talar component, requiring reconstruction arthrodesis.

The cause of these cysts remains unclear. The hypothesis of the present study was that comparison between histology and radioclinical analysis can account for the onset of severe periprosthetic osteolysis with the AES TAR.

Material and methods

Patients

A continuous series of 80 patients with 84 AES implants underwent TAR between November 2003 and May 2008; surgery was performed by a single senior surgeon (JLB), in a single center, following a single protocol of surgery and postoperative rehabilitation.

Twenty of these patients (13 male, 7 female: 22 ankles) required surgical revision for periprosthetic osteolysis with threatening evolution or directly associated with mechanical complications.

There were 25 revision procedures: in eight cases, the implant was removed and arthrodesis was performed; 14 cases were treated by curettage and grafting of the cyst with replacement of the polyethylene bearing, and three of

these patients, treated conservatively, required reintervention by arthrodesis due to severe cystic recurrence (Fig. 1). In three cases, revision was performed in a different center, and the histology specimens could not be included in the present analysis: one patient underwent primary revision arthrodesis, and one was treated first by curettage and grafting, with arthrodesis 4 years later. The present analysis was thus founded on 22 histology specimens taken during revision of AES TARs. Two other patients from the series were scheduled for arthrodesis at the time of writing.

The initial TAR indication was post-traumatic osteoarthritis in 11 cases and osteoarthritis secondary to chronic ligament instability in the other 11 cases. Mean age at TAR was 50.5 years (range, 21–74 years).

Implant characteristics

The implants in question were AES (Ankle Evolutive System) TARs [13], manufactured by Transystem (Nîmes, France) and marketed by Biomet (Valence, France). The design was developed from the Buechel Pappas TAR, with three non-stressed non-cemented components. The tibial and talar components were in chromium–cobalt alloy (Co–Cr) with the mobile bearing in ultra-high molecular weight polyethylene (UHMWPE). Two versions were successively marketed: the first had a modular tibial component, with a Morse taper to adapt the tibial stem, and a hydroxyapatite (HA) coating; as of August 2004, this was replaced by a second generation AES TAR with a monoblock tibial stem and a coating comprising a thick layer of plasma-pulverized titanium covered by hydroxyapatite (Ti-HA).

Radiology

Prospective radiologic monitoring was systematic:

- plain AP and lateral weight-bearing ankle views, pre-operatively, postoperatively, at 6 months and then annually;
- 3D ankle CT scan, pre-operatively and at 3 and 5 years.

X-rays were analyzed on the protocol of Besse et al. [12] (Fig. 2).

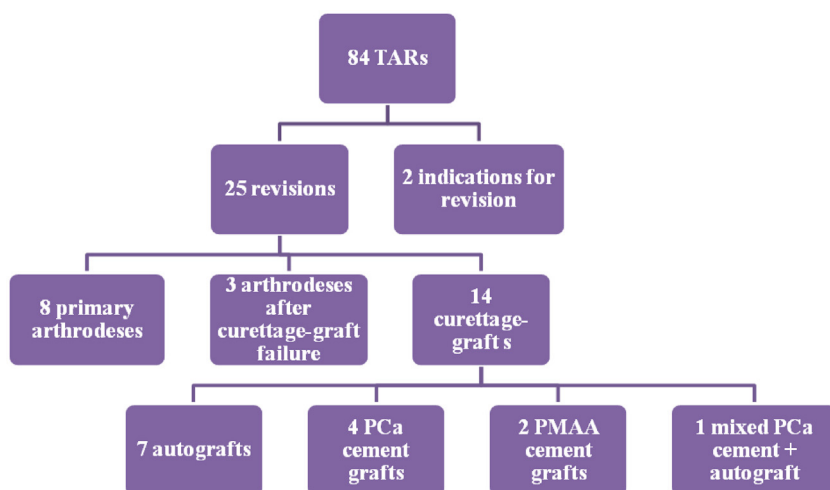


Figure 1 Patient distribution according to type of revision and of graft.

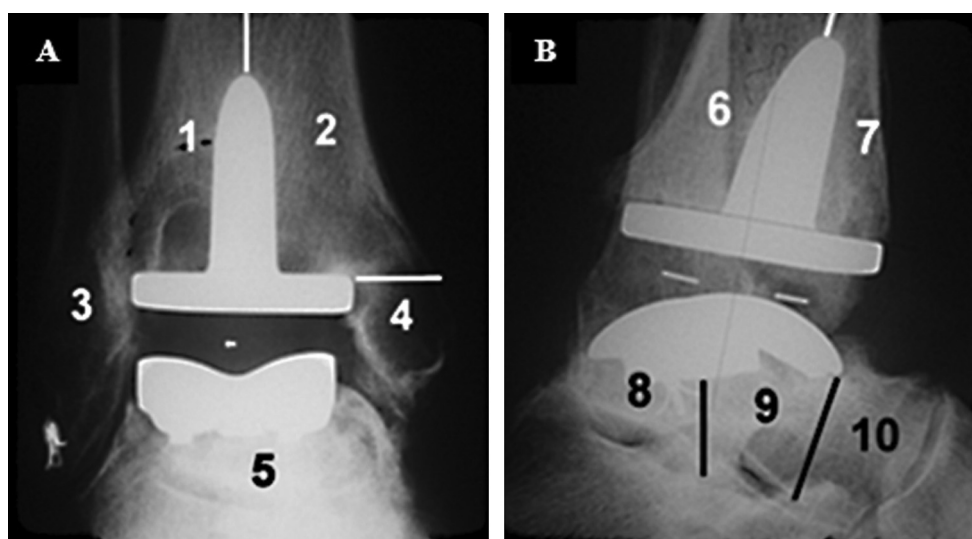


Figure 2 Plain X-ray periprosthetic osteolysis assessment protocol for AES TAR, following Besse. A. AP ankle view: Region 1: lateral tibia, Region 2: medial tibia, Region 3: lateral malleolus, Region 4: medial malleolus, Region 5: under talar component. B. Lateral ankle view: Region 6: posterior tibia, Region 7: anterior tibia, Region 8: posterior talus under implant, Region 9: anterior talus under implant, Region 10: talar neck and head. Lesion classification by size (mm) for all 10 regions: N = normal 0, L = lucency 0–2 mm, Cyst grade A = 2–5 mm, Cyst grade B = 5–10 mm, Cyst grade C = 10–20 mm, Cyst grade D = 20–30 mm, Cyst grade E = >30 mm.

CT scan was systematic before revision, to map lesions precisely and look for any cortical lysis.

Inclusion criteria and patient data

The indications for revision were:

- radiologically evolutive periprosthetic cysts of more than 3 cm diameter with risk of talar and/or tibial component collapse into the cysts;
- mechanical complications related to periprosthetic osteolysis: implant collapse into cyst or cortical lysis with painful microfracture.

None of the patients had history of ankle sepsis or signs of chronic or acute sepsis. The functional impact of the osteolysis was assessed using the AOFAS functional score [14] ahead of TAR, at 1 year postoperatively and ahead of revision.

Histology

The surgical specimens were fixed immediately in buffered formaldehyde solution. After inclusion in paraffin, 3–5 μ slices were prepared for slides with hematoxylin–eosin staining. All the samples were analyzed by senior pathologists of our center, who sent back written reports.

Between March and December 2012, all these samples were re-examined by a senior pathologist (RB) and a junior

surgeon (FD) under optical microscopy in standard and polarized light. A form was filled out for each slide, quantifying and describing the inflammatory reaction and necrosis, analyzing the synovial sheath and bone tissue, and noting any foreign bodies.

Results

The mean interval between TAR and revision was 59.8 months (range, 26–108 months). No macroscopic metallosis was found during revision. None of the polyethylene bearings showed macroscopic signs of wear.

Functional results

Mean AOFAS functional score was 37.3 (23–54) pre-TAR and 89.7 (78–100) at 1 year; by revision, this had fallen to 72.9 (40–100). This fall was mainly due to pain, with a mean pain score of 32.5/40 at 1-year post-TAR and 20.6 at revision.

Radiology results

Evolutionary osteolysis was found at the 1-year check-up for two patients, but for most was diagnosed on the second year radiographs. All patients had bipolar lesions (Table 1 and Fig. 3). On pre-revision CT, eight ankles showed tibial or talar cortical lysis. Six patients showed implant failure, implicating osteolysis: one medial malleolar fracture, and five cases of talar component collapse.

Histology results

A total of 94 specimens were analyzed. For each ankle, there were between three and eight specimens including at least one slide of synovial tissue, one of periprosthetic bone tissue and one of cyst contents (Tables 2 and 3).

The synovial sheath systematically showed abrasion and was often covered in fibrinoid necrosis (Fig. 4). There were no polynuclear infiltrates. Bone tissue showed signs of resorption with macrophagic granulomatous reaction in the medullary tissue, comprising histiocytes and polynucleate giant cells.

The “heart” of the cysts comprised acellular eosinophilic necrosis, free of foreign bodies. At the periphery of this necrotic region, there was a macrophagic inflammatory reaction of the same type as found in the bone tissue, but with a predominance of histiocytes; intensity was moderate in 73.3% of the samples and high in 15.7%.

Various materials were found within the inflammatory granulomas. Some bodies were clearly foreign: polyethylene or metal debris as classically described in resorption in contact with the implant. The polyethylene was in the form of colorless translucent fragments, strongly birefringent under polarized light; they were either large (20–25 μm) and extracellular, in contact with polynucleate giant cells, or smaller (2–5 μm), in the form of debris in the histiocyte cytoplasm, difficult to see under standard light but easily picked out under polarized light (Fig. 5). They were found in 68 samples (19/20 ankles: 95%): in 12 of the 13 cases of curettage-grafting and all seven cases of arthrodesis.

There were also metal particles (0.3–1.5 μm) within the cytoplasm of spumous histiocytes, found in 50 samples (12 ankles: 60%) (Fig. 6). Amounts were small, except in cases 5 and 19, but were found in all patients with HA-coated implants and in four (33.3%) of those with Ti-HA coatings. Microscopy was unable to determine whether the particles were of chromium, cobalt or titanium. It is noteworthy that the HA-coated models had modular tibial stems, adapted to the bearing by a Morse taper, which was found on revision to have come loose.

We also found a brownish pigment in the histiocyte cytoplasm (Fig. 7). The aspect did not suggest a formaldehyde pigment; it was negative on Perls' staining, and therefore

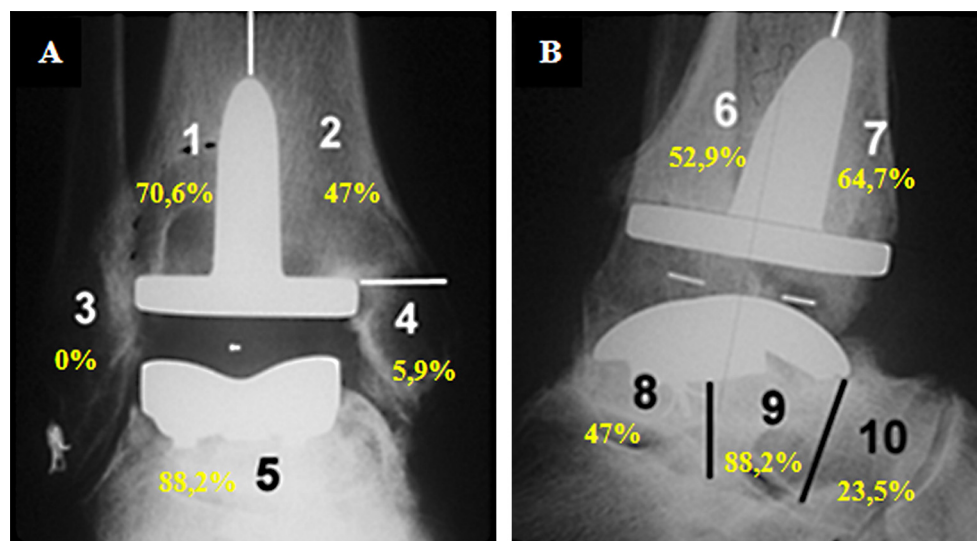


Figure 3 Distribution of grade C, D and E osteolytic lesions, in percentage, for each region, according to the plain X-ray periprosthetic osteolysis assessment protocol for revision of AES TAR.

Table 1 Radiologic analysis and osteolysis complications in the series of 20 patients.

	Side	Time to first cysts, and location	Pre-revision radiographic analysis (Besse protocol)	Implantation-revision interval (months)	Mechanical complications
Case 1	Left	2 years, tibia	Cysts C: regions 1, 6, 7/Cysts D: region 5/Cysts E: regions 2, 8, 9	107	Talar collapse
Case 2	Right	4 years, tibia and talus	Cysts B: regions 1, 6/Cysts C: regions 5, 7/Cysts D: region 9	108	Talar collapse
Case 3	Right	3 years, talus	Cysts D: regions 5, 9, 10/Lucency: regions 1, 2	57	Talar collapse
Case 4	Left	2 years, tibia	Cysts C: regions 5, 7, 8, 9, 10/Lucency: regions 1, 2	82	Cortical lysis
Case 5	Left	4 years, tibia and talus	Cysts C: regions 1, 2, 6, 7/Cysts D: regions 5, 8, 9	104	Cortical lysis
Case 6	Right	2 years, talus	Cysts C: regions 5, 7/Cysts D: regions 8, 9	92	0
Case 7	Left	2 years, tibia	Cysts C: regions 1, 2, 5, 6, 7/Cysts B: regions 8, 9	60	0
Case 8	Right	4 years, tibia	Cysts C: regions 2, 5, 9/Cysts D: regions 1, 6	83	Cortical lysis
Case 9	Left	2 years, tibia	Cysts B: regions 2, 5, 6/Cysts C: regions 1, 4, 7, 8, 9	42	0
Case 10	Left	2 years, tibia and talus	Cysts C: regions 2, 5, 7, 9, 10/Cysts D: regions 1, 6	50	Cortical lysis
Case 11	Left	2 years, tibia and talus	Cysts B: regions 6, 7, 8/Cysts C: regions 1, 2, 9/Cyst D: region 5	56	Cortical lysis
Case 12	Left	3 years, tibia	Cysts C: regions 5, 6, 9/Cysts D: regions 1, 7	48	Cortical lysis
Case 13	Right	2 years, tibia and talus	Cysts C: regions 5, 6, 9/Cysts D: regions 1, 2, 7, 8	49	Cortical lysis
Case 14	Left	2 years, tibia and talus	Cysts C: regions 1, 5, 6, 7, 8, 9/Cyst B: region 2	39	0
Case 15	Left	2 years, tibia	Cysts A: regions 5, 8, 9/Cysts B: region 4	30	MM fracture
Case 16	Right	1 year, tibia	Cysts C: regions 1, 5, 6, 9/Cyst D: region 2	45	Cortical lysis
Case 17	Left	1 year tibia	Cysts C: regions 1, 5, 8/Cysts D: regions 7, 9	51	0
Case 18	Right	2 years, tibia and talus	Cysts C: regions 1/Cysts D: regions 2, 5, 6, 7, 8, 9	73	Talar collapse
Case 19	Left	2 years, tibia and talus	Cysts C: regions 1, 2, 5, 6, 7/Cysts D: regions 8, 9	57	Talar collapse
Case 20	Left	2 years, talus	Cysts A: regions 2, 7/Cysts C: regions 5, 9, 10	26	0

MM: medial malleolus fracture.

not a hemosiderin pigment. It was found in nine samples (four ankles) from patients with HA-Ti-coated implants (33.3% of HA-Ti-coated implants). There were also 15–25 μm particles in the cytoplasm of giant cells; they had a pale, flakey aspect, non-refrigent under polarized light (Fig. 8). They were found in 12 samples (six ankles: 30%): 44.4% of HA-coated implants and 18.2% of HA-Ti-coated implants; these samples also showed metal and polyethylene particles.

In the two ankles (cases 5 and 8) that underwent curettage-grafting followed by arthrodesis, there was no difference on histology between the specimens from the two operations.

A preliminary study by X-ray diffraction and infrared spectrometry of two samples of cyst contents failed to determine the nature of the foreign bodies found in the periprosthetic tissue, as quantities were too small for the sensitivity of the techniques used.

Table 2 Anatomopathology results for the 13 cases with curettage-grafting conserving implant.

	Implant n° in series	Date of implantation (dd/mm/yyyy)	Type of coating	Implantation to revision interval (months)	Number of slides	Joint tissue	Talar tissue	Tibial tissue
Case 4	TAR N°10	01/12/2003	HA	82	3	Polyethylene: + Metal: + Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0
Case 5	TAR N°13	05/01/2004	HA	61	8	Polyethylene: +++ Metal: ++ Other material: +	Polyethylene: ++ Metal: +++ Other material: +	Polyethylene: ++ Metal: +++ Other material: +
Case 6	TAR N°14	02/02/2004	HA	92	6	Polyethylene: + Metal: + Other material: +	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0
Case 7	TAR N°16	16/03/2004	HA	60	3	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: + Metal: + Other material: 0
Case 8	TAR N°18	03/05/2004	HA	54	6	Polyethylene: + Metal: + Other material: +	Polyethylene: + Metal: + Other material: 0	Polyethylene: + Metal: 0 Other material: 0
Case 9	TAR N°25	25/11/2004	Ti-HA	42	3	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: + Metal: 0 Other material: 0
Case 10	TAR N°29	07/02/2005	Ti-HA	50	7	Polyethylene: + Metal: + Other material: +	Polyethylene: + Metal: + Other material: +	Polyethylene: + Metal: + Other material: +
Case 11	TAR N°30	15/02/2005	Ti-HA	56	4	Polyethylene: ++ Metal: + Other material: 0	Polyethylene: 0 Metal: + Other material: 0	Polyethylene: ++ Metal: + Other material: 0
Case 12	TAR N°32	17/03/2005	Ti-HA	48	4	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0
Case 13	TAR N°35	18/08/2005	Ti-HA	49	3	Polyethylene: + Metal: 0 Other material: +	Polyethylene: 0 Metal: 0 Other material: +	Polyethylene: 0 Metal: 0 Other material: +
Case 14	TAR N°37	13/10/2005	Ti-HA	39	3	Polyethylene: ++ Metal: 0 Other material: +	Polyethylene: ++ Metal: 0 Other material: 0	Polyethylene: ++ Metal: 0 Other material: +
Case 16	TAR N°40	05/01/2006	Ti-HA	45	4	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: 0	Polyethylene: 0 Metal: 0 Other material: +
Case 17	TAR N°42	30/01/2006	Ti-HA	51	3	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: + Metal: 0 Other material: 0	Polyethylene: + Metal: 0 Other material: 0

Table 3 Anatomopathology results for the 9 cases with ankle arthrodesis.

	Implant n° in series	Date of implantation (dd/mm/yyyy)	Type of coating	Implantation to revision interval (months)	Number of slides	Joint tissue	Talar tissue	Tibial tissue
Case 1	TAR N°3 Bis	10/07/2003	HA	107	8	Polyethylene: +++ Metal: ++ Other material: 0	Polyethylene: ++ Metal: + Other material: 0	Polyethylene: ++ Metal: 0 Other material: 0
Case 2	TAR N°4	02/09/2003	HA	108	4	Polyethylene: ++ Metal: ++ Other material: 0	Polyethylene: ++ Metal: + Other material: 0	Polyethylene: ++ Metal: + Other material: 0
Case 3	TAR N°9	17/11/2003	HA	57	3	Polyethylene: ++ Metal: + Other material: +	Polyethylene: ++ Metal: + Other material: 0	Polyethylene: ++ Metal: + Other material: 0
Case 5	TAR N°13	05/01/2004	HA	104	6	Polyethylene: +++ Metal: ++ Other material: +	Polyethylene: ++ Metal: +++ Other material: +	Polyethylene: ++ Metal: +++ Other material: +
Case 8	TAR N°18	03/05/2004	HA	83	8	Polyethylene: + Metal: + Other material: +	Polyethylene: + Metal: + Other material: 0	Polyethylene: + Metal: 0 Other material: 0
Case 15	TAR N°39	21/11/2005	Ti-HA	30	3	Polyethylene: + Metal: 0 Other material: +	Polyethylene: + Metal: 0 Other material: +	Polyethylene: + Metal: 0 Other material: 0
Case 18	TAR N°53	26/10/2006	Ti-HA	73	4	Polyethylene: + Metal: + Other material: +	Polyethylene: + Metal: ++ Other material: 0	Polyethylene: + Metal: + Other material: 0
Case 19	TAR N°63	17/04/2007	Ti-HA	57	8	Polyethylene: + Metal: + Other material: 0	Polyethylene: + Metal: ++ Other material: 0	Polyethylene: + Metal: 0 Other material: 0
Case 20	TAR N°84	17/04/2008	Ti-HA	26	3	Polyethylene: ++ Metal: 0 Other material: 0	Polyethylene: ++ Metal: 0 Other material: 0	Polyethylene: ++ Metal: 0 Other material: 0

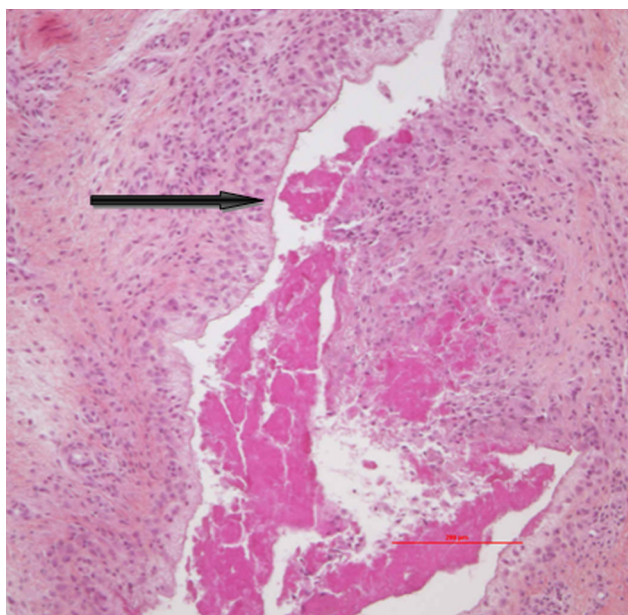


Figure 4 Necrotic material covering the synovium, with epithelial abrasion.

Discussion

Our experience with AES TAR finds a 28.6% rate of revision for severe evolutive periprosthetic osteolysis. Histologic analysis of revision specimens found two clearly identifiable types of foreign bodies related to implant wear: polyethylene, in 95% of the cases, but also metal particles in 60%. Two other types of material were associated, the nature and indeed the actual foreignness of which could not be determined: a brownish pigment, in 20% of the cases that was neither suggestive of the formaldehyde involved in the histology fixation liquid and technique nor a hemosiderin pigment, being negative for Perls' staining; and, in 30% of the cases, flakey cytoplasm inclusions found in macrophages.

The strong points of the present study lie in its continuous prospective design, involving a single senior surgeon. Histology specimens were re-analyzed by an independent senior pathologist. The weak point lies in the fact that the surface coating was changed in 2004, which may induce bias in the analysis of the pathology results and a limitation on the ability of a simple histologic examination to identify the exact nature of the material found.

The exact physiopathology of osteolysis is unclear. In hip arthroplasty, osteolysis is seen as a foreign-body reaction to cement and polyethylene wear debris [15,16]. Particles of polyethylene (UHMWPE), PMMA cement, chromium–cobalt (Cr–Co), titanium alloys, alumina (Al_2O_3) and zirconium dioxide (ZrO_2) are all implicated [17]. This biological activity, however, depends more on the size than the nature of the particles [18]. Particles of polyethylene, of any kind of metal (stainless steel, Co–Cr, titanium) or ceramic measuring less than $7\text{ }\mu\text{m}$ may be phagocytosed by macrophages, releasing pro-inflammatory cytokines [19–21]; this triggers a cascade of biological reactions, including the release of the receptor activator of NF-kappaB (RANK) which binds to the receptor activator of NF-kappaB ligand (RANKL),

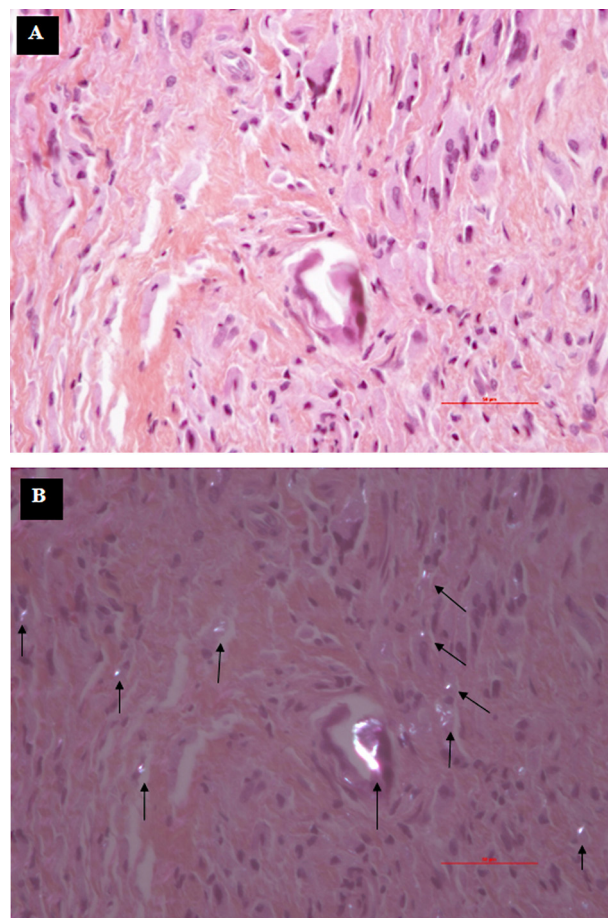


Figure 5 Histiocytic inflammatory infiltrate with a few giant cells ($\times 40$ lens). A. standard light; B. polarized light, revealing polyethylene particles in contact with a polynucleate giant cell.

inducing osteoclastogenesis and osteolysis and inhibiting osteogenesis [15,16,18,22,23].

Several reports of short- and medium-term findings with the AES ankle prosthesis focused on periprosthetic osteolysis and imaging of the bone/implant interface [12,24–27]. Koivu et al. [24] reported a 21% severe lesion rate at

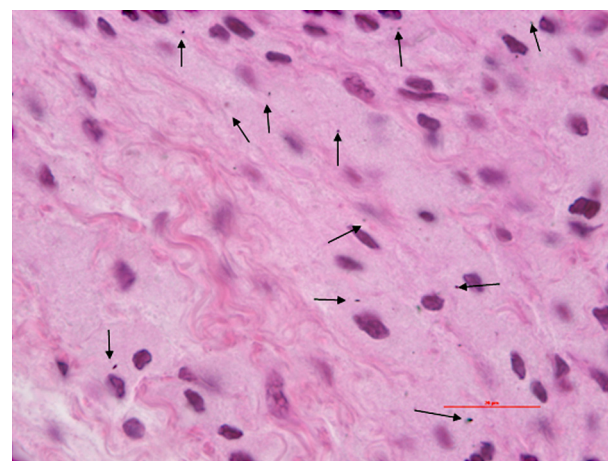


Figure 6 Inflammatory infiltrate with metal particles within histiocyte cytoplasm ($\times 100$ lens).

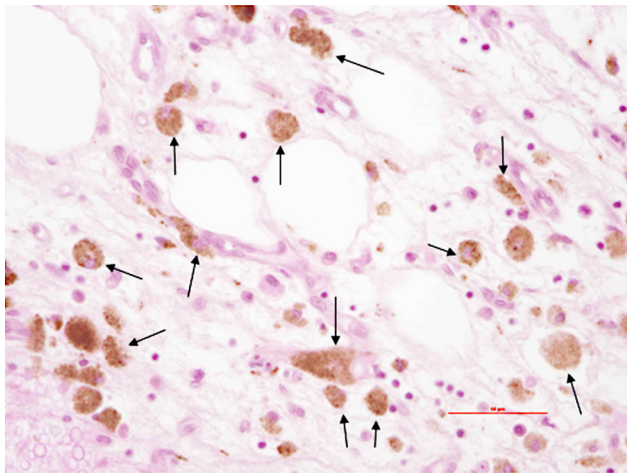


Figure 7 Brownish pigment around histiocyte nuclei ($\times 40$ lens).

31 months, Harris et al. [25] a 24% rate of significant lesions at 58 months, Leemrijse et al. [26] a 77% rate of cysts on radiographs and 100% on CT scans at 39 months, and Kokkonen et al. [27] a 79% rate of osteolysis and 40% rate of severe cysts at 28 months.

CT allows earlier detection of such lesions, especially those under the talar component, and precise monitoring of their evolution [12,28]. Periprosthetic osteolysis has also been reported with other TAR models, both the 2-component Agility implant [11] and 3-component designs [29–32].

Several hypotheses may be advanced to account for the elevated rate and early onset of evolutive cysts in the present AES TAR series.

The tibial stem fixation has been incriminated; cysts, however, also formed in the talus. The implant design as such would not seem to be implicated, as it is similar to that of the Buechel Pappas TAR, for which Buechel, the designer, reported 92% 10-year survivorship [8] and Doets (non-designer) 84% 8-year survivorship [29].

The problem may lie in defective implant positioning: fitting a TAR is more operator-dependent than fitting a hip or knee replacement [30]. In the present study, however,

there were no frontal or sagittal positioning defects of more than 5° , and 98% of implants were well centered [12].

Bonin et al. [31,34] suggested that some of the cysts found might have evolved from pre-existing arthritic cysts; the patients in this study [34], however, had not had pre-operative CT scans screening for pre-existing cysts, as was the case in the present series where the cysts investigated were not found on pre-operative scans but appeared between the first and second year postoperatively, showing rapid evolution. Moreover, in agreement with Koivu et al. [24], the present histologic study found metal particles and foreign bodies, suggesting that Bonin et al.'s hypothesis [31,34] is mistaken.

The polyethylene of the mobile bearing may be subject to the greatest stress, shearing against the tibial component. However, the implication of polyethylene in these granulomatous formations, as found with polyethylene wear in hip replacement, is not the only possibility, given the early onset and rapid evolution of osteolysis with no macroscopic signs of wear found on the mobile part during revision surgery.

The AES model requires considerable bone resection in the tibia and talus, due to the thickness of the tibial component (5 mm), the horizontal talar section and the supplementary anchorage in the talar neck. This cancellous anchorage, in contrast to a subchondral anchorage [35,36], could account for the implants less satisfactory primary stability, with migration of wear debris [37]. The talar cysts, indeed, begin almost at the level of the talar component's anterior anchorage groove in the talar neck. There is as yet no evidence regarding these factors, which remain hypothetical and may possibly be associated.

In the present series, no patients free of cysts at 1 year went on to develop cysts later. The hypothesis we adopt is therefore that the AES TAR has insufficient primary fixation, leading to delamination of the 2-layer coating and foreign-body reaction to titanium and HA particles, as described by Koivu et al. [24].

The metallurgy and polyethylene of the implants could in principle be implicated, but all later tests confirmed that they meet current standards.

With the first generation AES models, large amounts of metal particles were found, probably due to the modular design of the tibial stem; with second generation models, brownish pigments were found, which may have come from the Ti-HA coating. The new 2-layer Ti-HA coating may lead to delamination by fretting during the consolidation of the biological bone anchorage. The titanium particles and chromium and cobalt ions probably come from shear stress detaching them from the coating, leading to the resorptive inflammatory reaction seen in histology. Koivu et al. [24] reported the only histologic analysis of AES TAR revision specimens, with results identical to those of the present study: central acellular necrosis for the cystic formations and histiocytic macrophagic granulomatous inflammation mainly in contact with polyethylene and metallic foreign bodies. In the present study, metallic particles, when present, were not numerous. The bone tissue was in resorption, with rarefaction of osteoblasts. Like Koivu et al., we interpret this histologic aspect as a foreign-body reaction. Metallic particles were found in all eight patients with HA-coated implants, whereas four of the patients with Ti-HA coating showed the brownish pigment discussed above

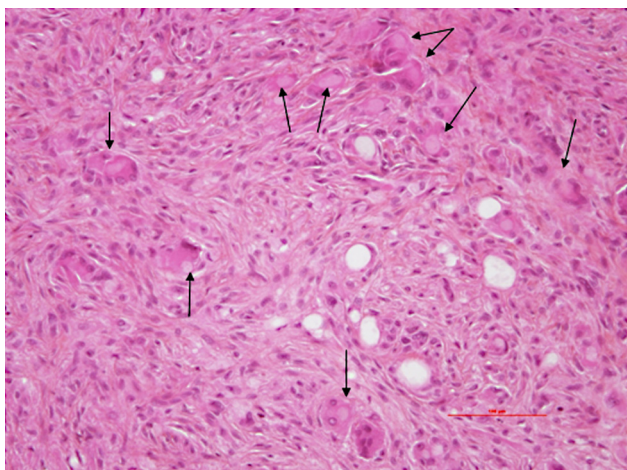


Figure 8 Pale flakey material in giant cells ($\times 20$ lens).

and four others showed metallic particles; the brownish pigment was never associated with an HA coating, and could derive from particles coming from the Ti-HA, although it was not possible to demonstrate this and, to the best of our knowledge, no studies have been made of this phenomenon; histopathology alone is unable to determine the exact nature of the metal and certain other foreign particles [38].

To confirm the implication of the 2-layer coating in the genesis of these osteolytic lesions, it would be necessary to be able to study the adherence of the titanium and hydroxyapatite coating of AES TARs in comparison with the coatings of other implants on the market. This information was not included in the national health insurance coverage approvals delivered in 2005 for the four implants authorized in France: AES, Hintegra, Salto and Star. Moreover, the version of the AES implant that was approved in 2005 had a purely hydroxyapatite coating, and the subsequent abolition of modularity and the introduction of the 2-layer coating were not mentioned to the authorities. Unfortunately, the distributor, Biomet, was unable to provide us with unused implants for testing.

Conclusion

TAR osteolysis is a worrying phenomenon, and is more frequent with the AES implant, jeopardizing stability.

The physiopathologic mechanism involved is poorly understood, although wear debris from polyethylene and also titanium, chromium, cobalt and perhaps hydroxyapatite seem to be at the origin of this cell-mediated inflammation. The TAR models currently on the market in Europe are made of the same materials as the AES and have a 2-layer Ti-HA coating; it is thus possible that the issue arises even for the implants currently authorized in France.

There are very few independent series in the literature that could shed light on survivorship. Indications should therefore be made with caution and the bone/implant interface should receive regular surveillance.

Disclosure of interest

J.L. Besse: assessment contract with Biomet company (2005–2008).

Other authors: no conflict to declare.

References

- [1] Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Hintermann B. Sports and recreation activity of ankle arthritis patients before and after total ankle replacement. *Am J Sports Med* 2006;34:993–9.
- [2] Hintermann B, Valderrabano V. Total ankle replacement. *Foot Ankle Clin* 2009;8:375–405.
- [3] Gougoulas N, Khanna A, Maffuli N. How successful are current ankle replacements? A systematic review of the literature. *Clin Orthop Relat Res* 2010;468:199–208.
- [4] Fevang BT, Lie SA, Havelin LI, et al. 257 ankle arthroplasties performed in Norway between 1994 and 2005. *Acta Orthop* 2007;78:575–83.
- [5] Henricson A, Skoog A, Carlsson A. The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005. *Acta Orthop* 2007;78:569–74.
- [6] Skyttä ET, Koivu H, Eskelinen A, Ikävalko M, Paavolainen P, Remes V. Total ankle replacement: a population-based study of 515 cases from the Finnish Arthroplasty Register. *Acta Orthop* 2010;81:114–8.
- [7] Karantana A, Hobson S, Dhar S. The Scandinavian total ankle replacement: survivorship at 5 and 8 years comparable to other series. *Clin Orthop Relat Res* 2010;468:951–7.
- [8] Buechel Sr FF, Buechel Jr FF, Pappas MJ. Twenty years evaluation of cementless mobile-bearing total ankle replacements. *Clin Orthop* 2004;424:19–26.
- [9] Kofoed H. Scandinavian total ankle replacement (STAR). *Clin Orthop Relat Res* 2004;424:73–9.
- [10] Kofoed. Reflection on total ankle replacement. In: Leemrijse TH, Valtin B, editors. *Pathologie du pied et de la cheville*. Paris: Elsevier Masson ed; 2009. p. 390–2.
- [11] Knecht SI, Estin M, Callaghan JJ, Zimmerman MB, Alliman KJ, Alvine FG, et al. The Agility total ankle arthroplasty: seven to sixteen-year follow-up. *J Bone Joint Surg Am* 2004;86:1161–71.
- [12] Besse JL, Brito N, Lienhart C. Clinical evaluation and radiographic assessment of bone lysis of the AES total ankle replacement. *Foot Ankle Int* 2009;30:964–75.
- [13] Asencio J-G, Leonardi C. Ankle Evolution System prosthesis: a simple accurate and reliable specific concept for primary and revision ankle surgery. *Tech Foot Ankle Surg* 2005;4:119–24.
- [14] Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, mid-foot, hallux, and lesser toes. *Foot Ankle Int* 1994;15:349–53.
- [15] Purdue PE, Koulouvaris P, Nestor BJ, Sculco TP. The central role of wear debris in periprosthetic osteolysis. *HSS J* 2006;2:102–13.
- [16] Holt G, Murnaghan C, Reilly J, Meek RMD. The biology of aseptic osteolysis. *Clin Orthop* 2007;460:240–52.
- [17] Archibeck MJ, Jacobs JJ, Roebuck KA, Glant TT. The basic science of periprosthetic osteolysis. *Inst Course Lect* 2001;50:185–95.
- [18] Ollivier B, Wimbush JA, Clark IM, Donell ST. Current concepts in osteolysis. *J Bone Joint Surg Br* 2012;94:10–5.
- [19] Horowitz SM, Doty SB, Lane JM, Burstein AH. Studies of the mechanism by which the mechanical failure of polymethylmethacrylate leads to bone resorption. *J Bone Joint Surg Am* 1993;75:802–13.
- [20] Catelas I, Petit A, Zukor DJ, Marchand R, Yahia L, Huk OL. Induction of macrophage apoptosis by ceramic and polyethylene particles in vitro. *Biomaterials* 1999;20:625–30.
- [21] Hollak CE, van Weely S, van Oers MH, Aerts JM. Marked elevation of plasma chitotriosidase activity: a novel hallmark of Gaucher disease. *J Clin Invest* 1994;93:1288–92.
- [22] Crawford R, Sabokbar A, Wulke A, Murray DW, Athanasou NA. Expansion of osteoarthritic cyst associated with wear debris. *J Bone Joint Surg Br* 1998;80:990–3.
- [23] Jacobs JJ, Hallab NJ, Urban RM, Wimmer MA. Wear particles. *J Bone Joint Surg Am* 2006;88:99–102.
- [24] Koivu H, Kohonen I, Sipola E, Alanen K, Vahlberg T, Tiusanen H. Severe periprosthetic osteolytic lesions after the Ankle Evolution System total ankle replacement. *J Bone Joint Surg Br* 2009;91:907–14.
- [25] Morgan SS, Brooke B, Harris NJ. Total ankle replacement by the Ankle Evolution System: medium-term outcome. *J Bone Joint Surg Br* 2010;92:61–5.
- [26] Rodriguez D, Bevernage BD, Maldague P, Deleu PA, Tribak K, Leemrijse T. Medium term follow-up of the AES ankle prosthesis: High rate of asymptomatic osteolysis. *Foot Ankle Surg* 2010;16(2):54–60.

- [27] Kokkonen A, Ikävalko M, Tiihonen R, Kautiainen H, Belt EA. High rate of osteolytic lesions in medium-term follow-up after the AES total ankle replacement. *Foot Ankle Int* 2011;32:168–75.
- [28] Hanna RS, Haddad SL, Lazarus ML. Evaluation of periprosthetic lucency after total ankle arthroplasty: helical CT versus conventional radiography. *Foot Ankle Int* 2007;28:921–6.
- [29] Doets C, Brand R, Nelissen R. Total ankle arthroplasty in inflammatory joint disease with use of two mobile-bearing designs. *J Bone Joint Surg Am* 2006;88:1272–84.
- [30] Schutte BG, Louwerens JW. Short-term results of our first Scandinavian total ankle replacements (STAR). *Foot Ankle Int* 2008;29:124–7.
- [31] Bonnin M, Gaudot F, Laurent JR, Ellis S, Colombier JA, Judet T. The Salto total ankle arthroplasty: survivorship and analysis of failures at 7 to 11 years. *Clin Orthop Relat Res* 2011;469:225–36.
- [32] Preyssas P, Toullec E, Henry M, Neron JB, Mabit C, Brilhault J. Total ankle arthroplasty – three-component total ankle arthroplasty in western France: a radiographic study. *Orthop Traumatol Surg Res* 2012;98(Suppl. 4):S31–40.
- [34] Bonnin M, Judet T, Colombier JA, Buscayret F, Graveleau N, Piriou P. Midterm results of the Salto total ankle prosthesis. *Clin Orthop* 2004;424:6–18.
- [35] Aitken GK, Bourne RB, Finlay JB, Rorabeck CH, Andreae PR. Indentation stiffness of the cancellous bone in the distal human tibia. *Clin Orthop* 1985;201:264–70.
- [36] Hvid I, Rasmussen O, Jensen NC, Nielsen S. Trabecular bone strength profiles at the ankle. *Joint Clin Orthop* 1985;199:306–12.
- [37] Younger A, Penner M, Wing K. Mobile-bearing total ankle arthroplasty. *Foot Ankle Clin* 2008;13:495–508.
- [38] Cordonnier C, Sevestre M, Gontier MF. Foreign bodies after total hip prosthesis. *Ann Pathol* 1997;17(2):100–8.